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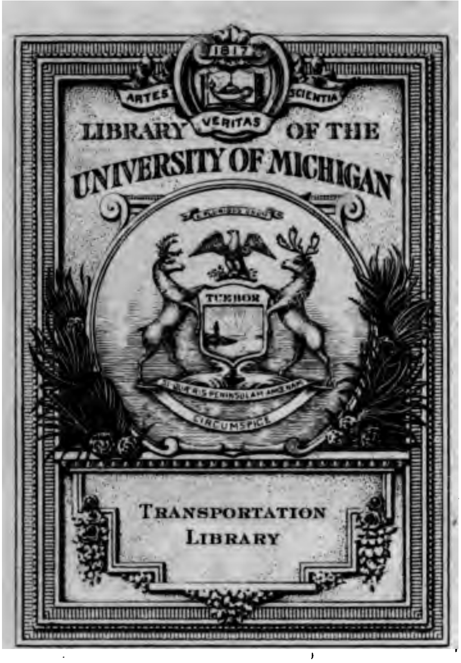

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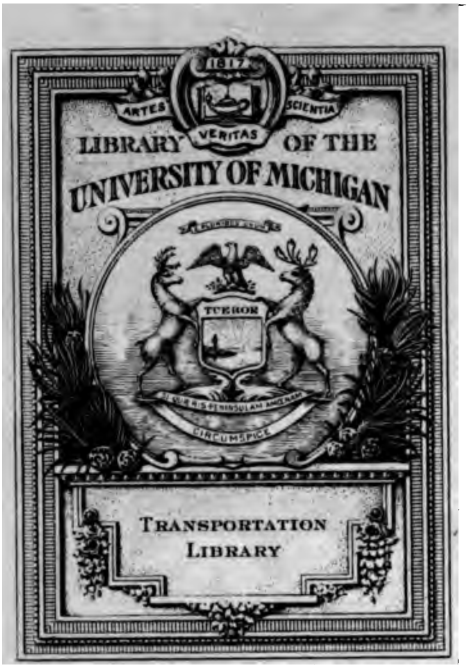

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THE FACILITIES OF

"FLEXIBLE" ROLLING STOCK

FOR

ECONOMICALLY CONSTRUCTING, MAINTAINING, AND WORKING

RAILWAYS OR TRAMWAYS.

BY

J. W. GROVER, MEM. INST. C.E.,

AUTHOR OF 'ESTIMATES AND DIAGRAMS OF RAILWAY BRIDGES,' 'THAMES VALLEY OUTFALL,' &c., &c

> "A little Management may often evade Resistance which a vast force might vainly strive to overcome."—*Anon.*

LONDON:
E. & F. N. SPON, 48, CHARING CROSS,
—
1870.

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UNIV. OF MICH.

on five shillings' worth of coals; but eight horses cannot do the same amount of work, nor be maintained at that sum.

An intermediate class of railroad is still necessary, over which carriages may be hauled at a speed of 16 miles, and along which goods trucks may be drawn at 10 miles an hour, by steam power.

There are numerous districts in this country of 200 to 400 square miles area where such cheap lines would be invaluable—to the landowner, to the miller, and farmer, no less than to the general public. There are many disused tramways in the midland and northern counties which might be converted into these light railroads.

Moreover, there are many canals now useless which might also be so adapted at very low costs, and be remunerative.

Again, the waste green spaces by the side of our turnpike and public roads are of no use as they are, and might be laid with metals for light railways.

In view of the importance of this necessity, and of the impossibility of satisfying its requirements by the existing carriages and waggons, I have designed the "Flexible Rolling Stock," which can be built so as to traverse very sharp curves, and yet be capable of being coupled to the trains of the main lines. I believe that this principle, when developed, will fully satisfy the requirements of a thorough and complete system of locomotion, both at home and abroad.

There are other important questions involved in this consideration. Whence is the present universal depreciation of railway property? Except main lines, between large cities, the system does not, and never will pay, as it is now carried on. Even on our most favoured lines, a 5 per cent. dividend is considered satisfactory, and 7½ most exceptional; yet in Prussia 15 per cent. is declared, and 24½ per cent. not unknown. Yet watch the traffic of our lines; it is enormous—too much for two pairs of rails—enough for three, or even four lines. Trains every ten minutes, stations enlarging, trade increasing daily; yet no more prosperity—5 to 7 per cent. the limit.

The Board of Trade returns show a terrible picture, on the branch line side. I can but refer to those documents, which are published to the world.

Yet railways can do better—as they do abroad; treat them with ordinary commercial prudence; deal with their freights as an ordinary carrier would deal with his goods; do not send a *waggon with four horses to take a carpet bag*; do not maintain an elephant to carry an infantry soldier's kit. Yet, weight for weight, this is actually less than railways do. How can they pay?

More especially the following pages refer to the reduction of the cost of construction, maintenance, and locomotive power of railways by "Flexible" or bending rolling stock, which will not only run smoothly and easily round sharp curves, but on straight lengths will effect a large saving, by yielding to those numerous inequalities which the best permanent way offers to implacable tires and axles.

The railway community should remember the words of Cicero, "*The world has not yet learned the riches of frugality.*"

THE

FACILITIES OF "FLEXIBLE" ROLLING-STOCK.

IN this country "Light" Railways have been made legal by Parliament in the recent *Railways Regulation Act of* 1868. These railways are intended to be surface lines, following generally the contours of the country, and consequently their gradients are necessarily heavy and their curves sharp. By this means the works are reduced, and heavy first cost is avoided.

Now a "Light Railway" is intended to carry the ordinary waggons and carriages of the main lines, but to be worked by a much lighter class of engine, and the speed on it is not to exceed *twenty-five miles an hour*. Under these circumstances the Board of Trade has consented to relax its stern requirements in works and rails; and though bridges and stations may in future lack some majesty, they will be more likely to result in dividend. Such lines will be something between a tramway and a railroad, and their cost here will range from 2000*l.* to perhaps 3000*l.* a-mile, according to the physical conformation of the country, exclusive of land.

Now it may be interesting for a moment to consider the commercial prospect of these undertakings; let us deal with round numbers and this country.

The main lines, we find, have averaged generally 30,000*l.* a-mile, and the branches about 10,000*l.* a-mile: to pay a dividend of 5 per cent. on this last cost, after allowing 50 per cent. for working expenses, 20*l.* a-mile a-week must be earned.

By turning to the Board of Trade returns, we find that though the average earnings of the Railways in the United Kingdom amount to 60*l.* per mile per week; yet some lines in the agricultural districts of Ireland, and a few branches in England, only earn 7*l.* to 8*l.* a-mile a-week. Consequently these should not have cost more than 2000*l.* or 3000*l.* a-mile in their construction. Even then slow speeds and few trains must be adopted, and moreover those trains must not carry from 30 to 70 tons of wood and iron dead weight to each ton of passengers, as they generally do on branch railways now. The Continental system of running only that number of carriages which will fill must be followed resolutely, the public notwithstanding.

Now a Railway is constructed on certain *gradients*, *curves*, and *straight lengths*, and the limits of the two first govern its cost. The object, therefore, is to determine these limits; and the more they can be extended, the nearer can the surface of the ground be followed and works reduced.

1. What are the limits of *gradient?* If we take two pieces of clean iron, and lay one on the other, and gradually lift one end of the lower one till the superincumbent piece begins to slide, we shall observe that this sliding takes place at a slope

somewhere between 1 in 4 to 1 in 6; this, therefore, is the ultimate coefficient of friction, and varies according to the condition of the surfaces of the metal.

Let the superincumbent piece of iron be taken to represent an engine; the lower one the rail: the wheels of this engine being locked and prevented from turning, it will just stand on 1 in 4 to 1 in 6. Therefore, when the wheels are caused to rotate, it can just climb this steep gradient, under the most favourable circumstances.

But fogs, rain, and sleet, prevent this result from being depended upon; and engineers seem to agree that 1 in 10 is the maximum slope that can be ascended in all weathers here. Taking this, therefore, as the datum; up half that gradient, or 1 in 20, the engine can haul a weight equal to itself; and up one-third of that gradient twice its own weight, and so on.

Near Aberdare Junction, on the Navigation Incline of the Taff Vale Railway, there is a good practical illustration of this to be seen in daily operation.

The gradient is for a quarter of a mile steeper than 1 in 18, the average for half a mile is 1 in 20. It was formerly worked by ropes, but now by the adhesion of an ordinary locomotive, which takes up it a load greater than its own weight—*viz.* 45 tons—the engine weighing 36 tons.

In America, on the Baltimore and Ohio Railway, instances are recorded of engines taking loads from half to equal their own weight up 1 in 10 ('Proceedings

Inst. C. E.,' vol. xxvi., p. 330), but in that climate the circumstances are much more favourable than in our own.

Between Manchester and Oldham, where the traffic is enormous, the gradients reach as high as 1 in 27; and ordinary locomotives weighing 29 tons with six coupled wheels climb this, with loads behind them of from 60 to 80 tons; and Mr. Hawshaw informs us that "the average working expenses are not greater than on other lines which had not these heavy gradients." And this remark seems to be well illustrated by the Lancashire and Yorkshire Railway, which, notwithstanding very heavy gradients throughout, pays well; whereas the Great Western, with scarcely any gradients at all on the main line, does not.

From these data it appears that 1 in 20 may be used, but to be quite safe 1 in 30 may be taken for Light Railways. And on this last, the engine with coupled wheels may be reckoned to take at least twice its own weight of load; that is, a 20-ton engine will draw 40 tons, or four carriages containing 160 people, more than sufficient for a poor district.

Now 1 in 30 is 176 feet rise in a mile; and this practically commands most countries. One in 20, we are told, on good authority, will climb many parts of the Andes.

We now come to *curves*, which have hitherto one fatal objection, they greatly increase the resistance of the train; consequently, engineers seldom attempt in general practice anything sharper than 10 chains or 660 feet radius.

Hence it follows that the great desideratum is some system by which the injurious effect of curves may be avoided; so that hills and property may be passed round, and not cut through.

Some very interesting experiments have been made on the Queensland Railway, on a gauge of 3 feet 6 inches, with trucks having wheels of only 2 feet diameter, with the small wheel base of 7 feet, which proportionately on the ordinary English gauge of 4 feet 8½ inches would be 9 feet 5 inches. Now these experiments (see 'Engineering,' October 29, 1869) give somewhat anomalous results, from which, however, the following facts may be gathered. With the stock named, and at very low speeds, the resistances were increased from one-eighth to double, on curves from 57½ chains to 5 chains radius.

The mean frictional resistance per ton being under 17 lbs., the curve of 57½ chains caused an increase of 2¼ lbs.; whilst on 5 chains radius that resistance was increased by nearly 18 lbs., or doubled.

That is to say, it would take twice as much power to pull the train round a 5-chain curve as it takes to move it on the straight, at only 10 miles an hour. Of course, as the speed increased, the resistance would be very much higher.

The above result seems to be curiously verified by some investigations made by Mr. Isaac in another part of the world—in America. He stated that a curve of 400 feet radius doubles the resistance on the straight (see 'Proceedings Inst. C. E.,' vol. xviii., p. 59). Consequently, the wear and tear of tires, carriages, engines, and rails, is doubled, and also the maintenance of the way.

Now let us look at an ordinary vehicle upon a common road, turning sharply the corners, without distress in its efforts to get round. How is this vehicle composed? Of four wheels, running loose upon two axles. The hinder axle is rigidly fixed to the framing of the carriage; but the fore axle turns upon a pivot, in any direction to which the motor, the horse, may lead. The front wheels, in fact, constitute a two-wheeled bogie; but the hind wheels are rigidly fixed to the carriage body, as in the case of ordinary railway rolling stock.

Now let it be for one moment conceived that road carriages had not this pivoting arrangement to the first axle, what would happen? The vehicle would travel in a perfectly straight line, and on a smooth road, without distress; but the first attempt to go to the right hand, or the left, would cause a severe draught upon the horse, and cut up the road, to the disgust of the highway surveyors, besides doing mischief incalculable to the wheels and axles. Yet this is precisely what takes place, only in a much more aggravated degree, on Railways. For in the case of the carriage with fixed axles, the wheels run loose and independently, so that in them at least there would be only lateral friction; but to make the simile perfect, we must connect our road carriage wheels rigidly together, by keying them to their axles, and suffering those axles to turn in journals.

It does not require any very great mechanical knowledge to show, that this system applied to an ordinary four-wheeled phaeton would render its draught so great as to make it useless; yet this is the system on Railways.

Is it to be wondered, then, that the total annual cost for maintenance and renewal of the permanent way of Railways is above 9 *per cent. of their gross receipts*—in the year 1866 amounting to 3,466,668*l.* on the 13,854 miles; and assessing the average life of a rail to be ten years, it would require 243,852 tons, which, at a cost of 7*l.* per ton, is equal to 1,706,964*l.* annual expenditure.

(See 'Proceedings Inst. C. E.,' vol. xxvii., p. 401, for these figures.)

Few but practical men have any idea how large a portion of the expense belongs to renewals and maintenance of way, and carriage and waggon stock, and hauling power.

In 1866, on a length of 13,854 miles:—

	Per cent. of Working Expenses.
The maintenance of way and works cost	18·43
The locomotive power	27·93
Repairs and renewals of carriages and waggons ..	8·18
Traffic charges (coaching and merchandize) ..	28·72
Rates and taxes	4·02
Government duty	2·47
Compensation for personal injury	1·63
Ditto loss and damage of goods ..	0·95
Legal and Parliamentary	1·44
Miscellaneous expenses	6·23
Total working expenses	100·00

The total working expenses being to total receipts as 49 to 100.

	£.
Total working expenditure being	18,811,673
Net receipts	19,352,681
Total receipts	38,164,354

The three first items in the above Table—above half the whole working expenses—vary directly with the facility, or otherwise, with which the load can be propelled; therefore a very small improvement in this direction will give great results, both saving of locomotive expense, saving of tires and rails, and in repairs of stock itself, such repairs being manifestly principally rendered necessary by the bumping and vibration to which the vehicle is subject, from the implacability of the wheels on which it rolls and grinds.

Now, this rigid wheel-base causes the flange of the tire actually to cut and shear off the rail; and practical men know well the formidable grinding noise which is heard under an engine of ordinary type when going round a 10-chain curve.

Various expedients have been adopted to overcome this great curve friction. At the head of them all is the American "*bogie*" system, so well known that it need only be mentioned; and it is no small credit to the elder Stephenson that its introduction in that country was due to his advice.

Now, every one who gives his experience of railway travelling in the States agrees in this important fact, "that notwithstanding the great inferiority of the roads, the travelling there is like 'sailing,' and infinitely more agreeable and smoother than our own; and that there is less of that hard, unpleasant, *vibratory jar*, which causes nervous debility in those who travel daily long distances by our English lines, but more of the swinging sensation felt in a well-slung barouche. All this is due to the use of 'the bogie trucks,' and the swing motion and equalizing beams."

There is a variety of English patents for radial axles; but the most ingenious arrangement of all is that of the *Paris and Sceaux Railway*, over which an amount of talent has been displayed worthy of better practical results.

With the exception of the American "bogie" system, scarcely one of these patents can be said to be *practically* available for rolling stock.

The author of this paper having been called upon lately to advise on the subject, for a branch railway connecting some of the main lines of this country, became convinced of the necessity for something more than at present existed.

The reasons which influenced his mind may be briefly stated thus:

1. That *stock* adapted for curves should be equally suitable for straight lengths. This the bogie truck certainly is not.

2. That the American bogie trucks having *four wheels a-piece*, compelled the use of eight wheels to a carriage; to make this commercially practicable, *long bodies* had to be resorted to.

3. That the measure of the bogies' stability upon the line was the length of its wheel base; but the shorter that wheel base could be made, the easier it could traverse curves. Hence two opposing and antagonistic requirements, resulting in an unsatisfactory compromise, and inapplicable for freight stock, here.

4. That in the radiating axle patents now in use, *three axles and six wheels* have generally been placed under the carriage body, causing, as in the bogie system, the necessity for an unwieldly length of carriage; consequently inconvenient for passenger, and more so for freight stock.

5. The author considers that all stock should be short and handy; and for light lines, much lighter than it is at present made.

The principal objection to the broad-gauge stock was found, not to be when running in a train, for there it was safer and even proportionally lighter than the narrow-gauge stock, but in its station-life and the difficulties of handling it.

The observations of Mr. James Allport, the general manager of the Midland Railway, may be quoted here:

"The principal part of the work of a train is at the stations in the loading and unloading, and moving trucks and carriages from one point of the station to another, across turn-tables or traversers; and any one who had experience at a station worked upon the mixed gauge, or solely upon one or the other of the gauges, must have been struck with the great additional expense in working the broad-gauge plant at the stations. It was not difficult for a couple of men to move a narrow-gauge truck or carriage to any part of the station; but to shift the broad-gauge plant, horses must be employed."

6. Now admitting the force of the foregoing argument, four-wheeled stock alone appears available, and the question arises, Can the radiating principle be applied to this? Such were the reasonings which appealed to the writer's mind on considering practically this subject. And two systems alone appear to him to give any prospect of solution; one being the *Paris and Sceaux* arrangement, and the other being a four-wheel American carriage, having a "*caster*" movement similar to that by which chairs and tables are rolled about. The first, from its complexity, was discarded; and the second failed to give the necessary security and steadiness so indispensable in case of high speed, inasmuch as the pivot on which the carriage body rested did not come over the axle, but some distance before it.

The writer was consequently driven to consider whether some practical modification could not be adopted, and the result of his investigation has been the invention shown upon the adjoining Plate.

The carriage to be pivoted upon two truck-frames, one at each end,—each of which is to have two wheels. One truck of one vehicle to be coupled to that of the next by a central coupling at A, and also loosely, if necessary, by safety chains at the sides at B B. Small buffers or bumpers would be used between the trucks, so as to prevent rigidity, and give the slight play requisite on entering pieces of straight. The only part of the carriage frame which has to take the compressive, or buffing shocks, being the centre member, which it is proposed to provide with small auxiliary springs at C C.

The trucks under each carriage would be cross-coupled by two diagonal ties, so that the radiation of one axle would be transferred to the other, and an amount of stability given to the whole wheel base which the American caster arrangement, or bogie system lacks.

Each carriage can be uncoupled, shunted independently at stations, and the arrangement is applicable equally to backward or forward movement.

When the stock runs on ordinary lines, no alteration is requisite; or the trucks can be rigidly fastened to the frames by a pin, as shown at D, and so converted at once into rigid wheel-base stock.

The elements of security in this system are not single but manifold.

For instance, the cross-bracing assists the stability, besides securing radiation; but if anything happens to injure it, the axles are still secured by being connected in pairs.

The buffers assist stability also; but if taken away altogether, the draught of the forward vehicle tends to keep its axle in place, whilst the draw-bar of the trailing carriage keeps the axles of that carriage in their position.

The safety chain side-couplings guard against any defect in the centre coupling.

Only sufficient amount of radiation would be allowed for to meet the requirements of the sharpest curve on the line, so that assuming an extreme case of one carriage breaking away from its couplings on a piece of straight, the extreme error of obliquity which could be obtained would only be equal to that which would occur if the carriages had been built with rigid axles in the usual way, and had run over the sharpest curve on the line.

The trucks would be mounted on springs in the ordinary way, in addition to which the pivoting-centres are fitted with india-rubber rings, to act as an auxiliary spring, and to relieve any unusual strain on the diagonals or draw bars.

But the writer finds from experiment that the diagonal bracings serve another very important office. In passing round a curve the outer wheels have to pass over more space than the inner ones, consequently one wheel has a tendency to push and the other to drag. Now if by any simple means the error of the outer wheels could be corrected by the inner ones, we should obtain perfect equilibrium, and a normal radiation of the axles. Now the diagonal bracing does this, and perfect equilibrium is established; for by just as much as one wheel on the inner rail gets before one on the outer, by so much is it retarded by the opposite wheel on the outer rail.

In the existing system of rolling stock this of course occurs, inasmuch as the axles do find their way round; but this is done by the strength of the carriage frames, which have to take the cross-strain of the two diagonals through their members, indirectly and round all kinds of corners and joints, instead of straight from point to point, as by ties or struts shown.

Again, the diagonal bracing takes the whole of the strain of the draw-bars out of the carriage frames, consequently these frames can be very much reduced in strength.

One of the most important features in the proposed system is that of radiating the *buffers* as well as the *axles*. Buffers, or, as the Americans call them, "bumpers," are like notes in books, necessities, but disagreeable ones, which should be reduced to the minimum.

In the proposed arrangement india-rubber rings are sufficient to prevent shocks, and allow flexibility in passing from curve to straight, and so on.

Ordinary buffers are formidable excrescences of massive construction, with large wooden heads and long powerful weighty rods and springs. Mr. Robert Fairlie, in a recent pamphlet, drew attention to the obvious lateral pressure brought upon the rails by the unequal forces on the buffers in passing round curves, one pair being jammed up close and the other working quite loose, not even in contact. Mr. Fairlie, to obviate this, proposed to dispense with buffers and adopt curved ends and central couplings, and this arrangement is ingenious and a great improvement. Yet it is difficult wholly to dispense with buffers, or at least "bumpers." Some sort of fender in shunting is requisite to shelter the frames; so also starting a train of any length without buffers is very difficult, and this was found to be the case on the Paris and Sceaux Railway, where the connecting bars were first made rigid, but afterwards fitted with springs, whose very small elasticity was nevertheless sufficient to answer the purpose; a practical negation to the necessity for buffing gear as ordinarily understood by that expensive and cumbrous arrangement.

Finally, it is necessary only to allude to the *motor*. An engine on Mr. Fairlie's principle will go comfortably round a 50-feet radius, and this may be seen at that gentleman's works at Hatcham. But it is not necessary to adopt that arrangement; a small tank-engine can be made with a 5 or 6 feet wheel-base, on four wheels; and if of heavier construction, a further addition of another axle, on a Bissel's bogie, or with Adams's radial axles, will still allow it to traverse a small curve, so that the difficulty of curves has been fairly overcome in a locomotive. Again, a pair of these engines footplate to footplate will give double the power of one, if more is necessary. However, the consideration of the engine and its capability cannot be brought within the limits of this paper. I must, however, before leaving the subject, as briefly as possible allude to the general question of weights.

The friction on a common level road may be taken to average 70 to 80 lbs. a ton, according to the condition of the surface.

But if iron rails be well laid down upon that road, the friction or pull upon the horse may be reduced to about 10 lbs. to the ton, or from $\frac{1}{8}$ to $\frac{1}{7}$ of the former case. Hence the advantage of *Railways*.

Now if we assume that an ordinary omnibus when half full carries *thirteen passengers* weighing 1 ton, and with its horses weighs 2 tons itself, we have 1 ton of paying load *to two tons of non-productive load*, or as 1 to 2.* But in practice what is the case in Railways? Authorities agree that the dead weight hauled, bears to that of *paying* load the proportion varying from 30 to 70 times (see 'Times' articles of October 1869), consequently the whole benefit of rails is thrown away. For if they benefit sevenfold, yet the thirty or seventy fold dead weight which they seem to involve in practice, more than balances the gain. Simple as this obvious truth appears when plainly stated, it is curious that it should be still ignored. For on our daily journeys we see long trains of empty carriages rolling along to the detriment of their own tires and the rails upon which they run. How, under these conditions, can Railways be productive?

That is to say, if 1 ton can be hauled by a horse on a level macadamized road, 7 tons can be pulled by the same horse on rails, theoretically (in practice this amount may be considerably reduced; about 3½ tons is generally taken).

At the risk of being prolix I must repeat the argument, for it should be studied and learnt by every railway proprietor.

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* *Note.*—This argument is by no means new, but has never been answered properly.

Let me put this case simply. The half-empty omnibus weighs 3 tons; two tons of which do not pay, and one ton does. The regular practice on a Railway in carrying the same ton of passengers is to employ from 30 to 70 times its weight in wood and iron to do it.

If the omnibus, with its 3 tons weight, were put upon level rails, we might multiply it by seven, that is, 21 tons could be drawn with the same facility and power as the 3 tons were on the road.

But this advantage is more than thrown away by the enormous increase of dead weight of from 30 to 70 tons actually used. Hence Railways do not pay. *Hinc Illæ Lacrymæ.* How can this be avoided?

1st. By running at moderate speed, say 20 miles an hour—the stock being built for that speed—and *not* for 60 miles an hour, as at present. Express trains should have *express stock;* but all trains are not express, and therefore all the plant should not be made three times as heavy as is necessary to meet the special case.

2ndly. By the employment of only just as many carriages as will reasonably fill.

3rdly. By the use of Flexible Rolling Stock, which I believe could also make Light Railways as accessible and perhaps as universal as high roads.

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